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WATER SUPPLY AND SEWERAGE SYSTEM PLANNING FOR GREATER KARACHI

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CITY PLANNING DIVISION

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WATER SUPPLY AND SEWERAGE SYSTEM PLANNING FOR GREATER KARACHI

Carroll V. Hill[1] and Vance C. Lischer,[2] M. ASCE

SYNOPSIS

The authors were sent to Karachi Pakistan for three and one-half months in 1951 under the Point 4 Program of the United States Government to render assistance to the Pakistan Government with regard to the water and sewage problems of the capital city of Karachi. The assistance rendered was principally related to the review of a master plan for providing a new supply of water from the Indus river which had been developed by Pakistani engineers, and the study and development of a master plan for sewage collection and disposal. Pakistan is a relatively new nation, having developed out of the partition of India and the granting of independence to that sub-continent by Great Britain. Pakistan has shown much promise in its desire to become a great nation. It has a great interest in the United States and in engineering practice in this country. In addition to describing the highlights of the engineering projects studied in Pakistan by the authors, the paper also gives a brief resume of the economical and political background of the country as well as a discussion of some of the differences in engineering practice with that of the United States.

Constantly improved means of transportation and communication have brought the peoples of the earth into much closer relationship, one with another. The social and economic welfare of the people of one country is of growing concern to all other countries. Americans, because of their own historical traditions, probably express their most sympathetic attitude toward those countries which have launched upon a program to obtain economic independence primarily through their own efforts. Recently founded Pakistan is one of these countries.

Although statesmen of Pakistan have achieved prominence in the deliberations of the United Nations, few Americans are familiar with the country and its people. The authors had an opportunity to learn more about this country when they were sent there on a Point 4 program assignment to provide technical assistance to the Pakistan government. Under a contract between the State Department of the United States and the firm of Harland Bartholomew and Associates, the authors spent the latter third of 1951 in Pakistan to assist that government in a study of water and sewerage problems in its capital city of Karachi.

The Country

Despite the fact that the Pakistani and the Hindus collectively composed

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the bulk of the people of India, their respective religions set them apart throughout the years. Thus the partitioning of the sub-continent of India was inevitable when independence became possible. The partitioned portions of Pakistan—West Pakistan and East Pakistan—contained predominent numbers of Moslems, and Bharat (India) which composed about three-fourths of the original India, was principally occupied by the Hindus.

Western Pakistan, with an area of over 300,000 square miles, or nearly four and one-half times the size of Missouri, has a population of about 35 million people. Extending from the Arabian Sea for a distance of about 900 miles to the Himalayas, Western Pakistan is subject to extremes in climate ranging from hot desert temperatures to the freezing weather in the mountains. Much of the western part of Pakistan is devoted to agriculture, but since so much of the arable area is without adequate rainfall, irrigation is a necessity. The principal source for irrigated water is the Indus River, which flows into the Arabian Sea about 65 miles east of Karachi, a city with a population of about 1,250,000. Lahore, the second largest city, has a population of 950,000.

The much more densely populated Eastern Pakistan lies about one thousand miles to the east on the other side of India. Its 54,000 square miles of predominately level lowland contain a population of about 45 million. The climate is tropical and in contrast to the Western section, this portion of Pakistan experiences an abundance of rainfall. Two mighty rivers, the Brahmaputra and the Ganges, course through the country and afford the principal means of transport. Its people are mainly engaged in the raising of rice, jute and tobacco. Dacca, the largest city, with a population of 550,000, serves as the capital of East Pakistan.

Its People

The people of Pakistan are a mixed race much like the people of the United States. Aside from their dark skins, they have no distinguishing features such as is the case with the yellow and black races. Straight features predominate. Most of the men are stalwart and handsome. As a race they are proud and resourceful. The ancient custom of purdah, that of women wearing veils, is still widely prevalent and the women as a consequence keep to the background. However, there is a trend away from the tradition and women of the educated classes have discarded the veil and are entering business and welfare activities. One prominent woman whom the authors met operates a prosperous concrete pipe factory on the outskirts of Karachi. Her husband, who is an engineer, has other employment in Karachi.

The Moslems have a strict and highly moral religion which is the dominant and unifying force in their nation. We found them to be thoroughly honest and trustworthy. They are devoted to their families and raise their children to be good citizens. While the Moslem religion tolerates polygamy, there are very few Pakistani who have more than one wife. The engineers with whom the authors associated and with whom they had many discussions on religion, education and customs, pointed out that their religion insists that there be complete domestic accord when additional wives are taken. The other wife or wives must give their consent.

Economic Development

Pakistan's economic surpluses chiefly consist of jute and rice. With the development of synthetic fibers, the world market for jute becomes less

certain. Although East Pakistan produces surplus food, West Pakistan in recent years has experienced shortages in agricultural products and therefore has had to import cereals to sustain the population.

Industrial development is limited, and many problems must be solved before Pakistan can begin to supply her needs for manufactured products. Some mineral resources are available in the northern portion of West Pakistan, but little has been accomplished toward making full use of them in the country's economy. Until greater quantities of electric power are produced, much of the hoped-for industrial development must wait. Another handicap that must be overcome is the shortage of technically trained persons. Relatively few Pakistani at the time of partition possessed mechanical skills or technical knowledge, and it will be some time before adequate educational opportunities can be provided to offset this lack in technicians.

The absence of opportunities for work presents an unemployment problem of great magnitude. Until industries can be established and expanded, unemployment will continue in serious proportions. The government has set aside two large areas for new industry. New textile, paint, concrete, pipe, chemical and other types of manufacturing plants have been built, but they are still few in number and employ relatively few people. Government and enterprising individuals are anxious to expand industries, but until raw materials, machines, equipment, electric power and technical skills can be made available in much larger quantities, industrial development in the Karachi area must continue at a slow pace.

Karachi—An Overcrowded Capital City

The foregoing paragraphs provide a very brief background of Pakistan and its people. Like most countries, the principal focal point of the social and economic activities of Pakistan is centered in its capital city of Karachi, where the authors spent almost all of their allotted stay. It is in the capital city that some of the country's most serious problems are encountered. Here the extremes in the life of the Pakistani are most pronounced.

Overwhelmed by a refugee population brought about by one of greatest migrations in history, Karachi's population tripled itself in four years. In 1947 the old city and its immediate environs had a population of about 400,000. In 1951, after the bulk of the migration had taken place, the city numbered around 1,200,000 persons. The problems of food, shelter, and employment for the refugee population overshadowed all others. Pakistan's new-found government at the national, provincial, and local levels directed their principal efforts to meeting the needs of Karachi's refugee population.

Most serious of the city's problems were the housing of refugees and the provision of the basic services of water and sanitation. With only a very few trained engineers and technicians, the solving of these problems presented such a formidable task that assistance was sought from other countries. Possessed of many years of experience with water supply, housing and sanitation in the sub-continent, British engineers and technicians were assigned principal roles in the solution of the most pressing problems. As of 1951, few other nationalities were represented in the technical fields.

Acute Need for Housing

The sudden upsurge in population created an acute housing shortage. All existing residential structures, particularly in the poorer sections of the city

were dangerously overcrowded. As of 1951, only a small beginning had been made in the government housing program. Obviously because of the limited material and technical resources of the country, the provision of adequate shelter for 800,000 refugees could not be accomplished in one or two years time. Even though the basic shelter needs are relatively simple in a desert-like environment, the furnishing of cement in substantial quantities alone presents a huge task, especially since there was but one principal producing plant. Other building materials such as framing lumber for roofs and inner walls, were also available in but limited quantities. The refugees therefore were compelled to erect temporary shelters with salvaged canvas, straw and all sorts of makeshift materials. Established in concentrations designated by the government, these refugee settlements presented an awesome picture of crowding and dilapidation.

Water Supply and Sanitation Difficulties

Karachi's water supply, which was never plentiful prior to 1947, became extremely inadequate with the influx of the refugee population. At the time when the authors were in the city, the per capita domestic consumption amounted to but ten gallons* per day. Water in the poorer sections of the city and in the refugee settlements was provided from common taps. Purveyors of water were frequently seen, and as was to be expected, prices were extremely high.

With a very limited water supply and extensive overcrowding, sanitation became an increasingly serious problem. The sewerage collection system in the old portion of the city was frequently overtaxed and presence of raw sewage on street surfaces was not an uncommon sight—not to mention smell. The city has been spared from epidemics only because of the hot sunshine and the resistance of the people.

Transport in Karachi

Karachi's principal means of communication with West Pakistan is by a single railroad with few branches. Transportation between East Pakistan and the capital city is chiefly by water. A limited amount of communication is accomplished by air travel over India. As the major port city of the country, practically all the exported products and imports of West Pakistan are handled by Karachi trading interests. Improved highways are few and exist only between the large cities. For this reason, and since trucks are few in number, there is little long distance hauling by motor vehicles.

Much of the local movement of goods is by animal transport. Camels, bullocks and the little donkey are common sights on the streets of Karachi. Their replacement by motor vehicles will be gradual since both truck and motor fuel must be imported. Trams, propelled by diesel and gasoline motors, and buses provide limited urban transit for the people. This is supplemented by taxicabs, victorias, pedicabs, and many individual bicycles.

Technical Aid for a Determined People

All those who visit Pakistan cannot help but admire the accomplishments of its government, especially since the results have been attained in such a

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* Imperial gallons are used throughout in this paper.

short period of time. Suddenly faced with the task of establishing a new country with but few trained persons and with limited physical facilities, such as building space and office equipment, Pakistan's progress in the creation and operation of all essential governmental functions is little short of phenomenal. Probably no other activity demonstrates more clearly the resolute purpose of Pakistani. What has been achieved by them in government operations can be expected in other endeavors in due time. A principal effort in this direction has been the seeking of outside technical help.

Of particular interest to Americans is the assistance supplied by the United States through its Point 4 Technical Assistance Program and more recently the aid furnished by the Mutual Security Organization. Under the U. S. Technical Assistance Program, specialists have been sent to help the Pakistani farmer improve his agricultural methods. Others were sent to help government officials devise more efficient means for the erection of housing on a large scale. While in Karachi the authors became acquainted with three Americans who were piloting Piper Cub planes for the purpose of spraying locust-infested agricultural areas. As an added duty the Americans were training Pakistani pilots in the techniques of aerial locust control. Since 1951 the American Technical Assistance to Pakistan has been greatly increased.

Under the Technical Aid Program of the United Nations, representatives of member countries have been sent to Pakistan to provide assistance in housing, sanitation and education. As a participant in the organization of the Columbo Plan, Pakistan is destined to receive assistance in the form of an exchange of goods, equipment and technical skills.

The Greater Karachi Plan

The task of preparing a plan for the development of Pakistan's capital city of Karachi was assigned to Merz-Rendel-Vatten of Pakistan, an association of British and Swedish consulting engineers. It has therefore been commonly referred to as the MRVP plan. The authors of this plan based their forecast of the city's future growth upon the assumption that it would function as both a capital and a port city. Population was predicted to increase to at least two and one-half million by the year 2000. In its submitted form the plan provides for an ultimate population of 3.4 millions.

Plate 1 presents a reproduction of the essential elements of the MRVP plan. With the old city and the proposed government center serving as focal points, the planned expansion extends radially outward in tentacle fashion, with each segment constituting a satellite town. Accommodating 200 to 300 thousand people in neighborhood units of 40,000, these satellite communities are so designed as to be independent of the parent city except for overall administration. The residential areas of the neighborhood units are grouped around a center which provides space for religious, cultural, and business activities. Nearly all of the satellite towns have bordering ribbons of land set aside for industry.

Generously wide radial avenues provide for the inter-communication between the old city and the new satellite towns. Circumferential routes of spacious widths link the important outlying sections of the proposed greater city together. Contemplated cross sections of these proposed major thoroughfares provide separate channels for rapid tramways, motor vehicles, bicycles and pedicabs, animal transport and foot traffic. Access is limited and future grade separations are anticipated at all principal crossings.

An area of approximately 4,000 acres extending northeastwardly from the old city and up the Layari River valley has been set aside for a site for the Federal Capitol. Sites within this capitol reservation have been allotted for a parliament house, secretariat building, federal court building, residences for principal government officials, foreign mission offices and residences, hostels for parliament members and auxiliary structures. A large portion of the area is reserved for residences of government officials and workers, as well as other persons associated with the government functions. The allotments for building sites and residential areas are generously spacious, and afford ample opportunity for landscaped settings, gardens and recreation areas.

New Development in Karachi

Responsibility for the development of new sections of greater Karachi in accordance with MRVP plan, with the exception of the Federal Capitol and the Sind Industrial Trading Estates area has been assigned to the Karachi Improvement Trust, especially created for the purpose. Its initial efforts were devoted to the development of the Nazimabad colony, which lies just to the west of the Federal Capitol area. Staked out with streets and allotments of land, the area in the fall of 1951 was a scene of considerable construction activity. Erected housing for the most part consisted of simple one-story masonry structures and provided minimum accommodations. Development in the new areas included the installation of water mains and sanitary sewers.

The Karachi Improvement Trust was also engaged in the development of the Landhi industrial district which lies on the eastern side of Karachi. Only two or three industries had been erected at the time of the authors' visit. The majority of the industrial development has taken place in the centrally located Sind Industrial Trade Estates area north of the old city. It is here that practically all of the new factories have been built. The erected factories occupied but a very small portion of the allotted 5,000 acres. The absence of adequate water and electric power account for the limited development thus far.

As an initial step to increase Karachi's water supply, the Karachi Joint Water Board launched upon a program designed to double the capacity of the Haleji lake system. It is understood that this work has been completed so that now 20 million gallons per day are available from this source. The government's proposed plan for the principal expansion of Karachi's water supply centered on the proposal to supply water from the Indus river, 65 miles away, by means of gravity canals and conduits. It was primarily for the purpose of reviewing the plans prepared for this project that the authors went to Karachi.

Preparatory to expanding trade with other countries, the Karachi Port Trust has started on a program for the improvement and enlargement of the city's port facilities. The firm that prepared the MRVP plan had been engaged to prepare the necessary engineering plans. It was evident to the authors that the various government engineering and construction agencies had accomplished a great deal in the short interval between the time of partitioning and the fall of 1951. Unfortunately, information as to the actual progress since 1951 has been very limited as far as the authors are concerned. What information we have received seems to indicate that the government agencies are continuing to make headway, although perhaps at a somewhat slower pace. This may be due to a decline in the country's economic position because of recent food shortages in West Pakistan.

Engineering in Pakistan

The Pakistani are desirous of bettering their country and their engineers, and are hungry for knowledge and experience. This is exemplified by the desire for learning and the eagerness to help, shown by the Pakistani engineers who assisted in the work done by the authors.

The work assigned to the authors in connection with the water and sewerage problems of Karachi was of the broad overall planning type. This did not permit opportunity to use the Pakistani engineers to the extent which was probably expected in the application of the Point 4 technical assistance program. As a consequence, the authors were not able to appraise the engineering capacity of the Pakistani engineers to turn out finished designs.

The Pakistani engineers who worked with the authors were well educated, many of them having been trained in British schools, in English language schools of India and in American universities. They lacked experience and unfortunately in their new country there was not the opportunity for obtaining in-training experience which is the way good engineers are developed in any country where technical progress is evident.

The British engineers have the capacity, experience, and patience to produce major engineering projects using the help of the local engineers and artisans which facility, unfortunately for our new position in world affairs, is not shared by most American engineers. For example, the heads of the Pakistan Public Works Department, the Karachi Municipal Corporation, and the Karachi Improvement Trust were British, having only Pakistani subordinates. A major irrigation project on the Indus River at Hyderabad containing the Lower Sind Barrage was being designed and constructed with scarcely more than six British engineers directing the work. The American engineer must learn patience, understanding and tolerance before he can duplicate these feats and provide foreign aid of enduring value. The Pakistani have learned of American accomplishments in engineering and their new found freedom gives them opportunity to seek contact with American engineering practice.

The pace of work in Pakistan is leisurely. This is irritating to Americans who like to get a job done quickly. Work does not start till 9:00 and some times 10:00 a.m. The lunch period lasts from one and one-half to two hours. There is time out for tea morning and afternoon. The work day is over at 5:00 or 5:30 p.m. The work week is five and one-half days.

In the Moslem world, religion is the underlying force. There is emphasis on the spiritual man. The Moslem world is one of hardship. His religion teaches a Moslem to find contentment and satisfaction however poor his lot may be. The effect of the religion is evident in engineering offices. Prayers are offered in privacy and solitude by each devout Moslem two or three times during the work day. Religious holidays are frequent.

There is much emphasis among Pakistani engineers on degrees and titles. It was not uncommon for a calling card of an engineer to have as many as five and more initials designating organizations, degrees and achievements. The strangeness of this practice is more apparent to American engineers because it detracts from our opinion of engineers who indulge in it here.

There is no language barrier in carrying on engineering work in Pakistan. However, there are some new words and uses of words in engineering practice which cause confusion at first. Examples are given below:

Pakistani Terminology	American Corollary or Meaning
Bund	Dam or Dike
Barrage	Dam
FSL (Full Supply Level)	No similar term
Cusec (Pronounced as spelled)	CFS (Cubic feet per second)
Crore	Ten million
Lakh	One hundred thousand
RL (Reduced Level)	MSL (Mean Sea Level)
Nallah	Small stream or water course
Rising Main	Discharge or pressure transmission pipe line
Coefficient of Rugosity	Coefficient of Roughness
Reflux valve	Check valve
Tender	Bid

The terminology of Pakistani engineers is more foreign to us than ours to them. Our engineering text books are in every office. Many of the engineers with whom the authors worked had visited America or had actually received engineering degrees from our universities. Such references having American origin as Hazen and Williams, Hardy Cross, Scobey, and Parshall flume were not strange to them. All of our engineering basic data and formulae, stemming from British practice and that of other countries used in our engineering practice were known to them, or readily available in texts and publications already in their possession.

Conflicts in Engineering Practice

The Pakistani engineer is confused because of some of the conflicts between his practice and that of America. He asks the American engineer about them and explanations must be made. He considers their practice representative of British practice and, without full knowledge of the background of the foreign experience, an American engineer has difficulty in giving a good explanation.

An example of such a conflict is in sewer design. The Pakistani practice calls for three feet per second minimum velocity and six inch minimum diameter for laterals. Our practice of course is two feet per second and eight inches, respectively. A case was shown where using the local design practice a succession of drop manholes and excessive depth in a trunk sewer was required because of the large amount of fall needed in the laterals tributary to the trunk sewer. Assuming 1,000 feet of lateral, a minimum fall of 3.3 feet is required according to our standards, and 11 feet according to theirs. Even if six inch minimum size is retained, the acceptance of two feet per second minimum velocity in place of three feet per second would reduce the depth at the end of the sewer by six feet.

Pakistani sewerage practice calls for a manhole at the point where the house service is connected to a lateral. In closely built housing projects, there might be four house connections for each manhole. In such projects there might be manholes forty feet apart, each with a cast iron lid. Such practice would be considered extravagant in the United States. It would be more so in Pakistan. The frequency of clogging was given as the reason for the numerous manholes. Modern power driven sewer cleaning equipment might permit a departure from this practice at this time.

In Pakistani water works practice, a Hazen and Williams "C" value of 90

for the determination of carrying capacity was being used for cast iron pipe. The cast iron pipe in use had only the usual hot dip bituminous coating. With cement-lined pipe universally available in the United States, we can use a "C" value of 130 and even higher in pipe sizes over 20 inch diameter. As an example, the difference can result in being able to use 10 inch pipe in place of 12 inch pipe. The saving in the United States for the pipe alone would be approximately one dollar per foot, or approximately 23 per cent. The saving in Pakistan where all cast iron pipe must be imported would be even greater in her foreign exchange which is far more precious than its monetary value.

Another departure from usual American practice lies in the manner in which sanitary engineering works are designed and purchased. The usual procedure is to invite tenders (bids) from equipment manufacturers for the entire plant, including equipment and functional design. There is little opportunity to evaluate such factors as cost of structures to be designed and provided separately by the purchaser, or to evaluate the relative merits of the process or the equipment where detailed specifications as to these items cannot be prepared in advance. This practice naturally stems from the fact that qualified designing engineers in the specialties of sanitary, chemical, mechanical and electrical engineering involved in such projects are not available. It can often result in unsound engineering for the local projects. It denotes perhaps the vestige of practices founded in the unwise and selfish past development of an empire.

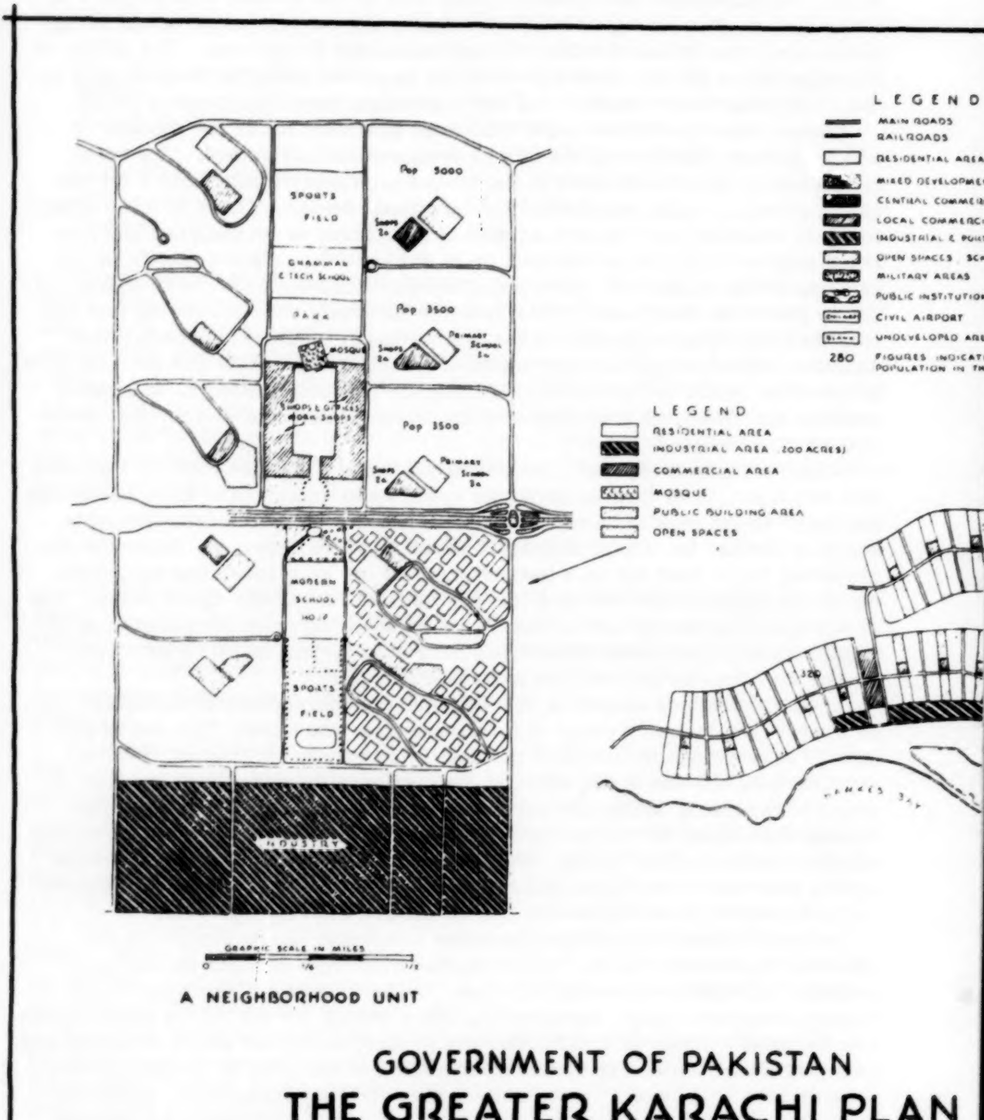
Sound, unbiased, objective consulting advice to countries such as Pakistan that are deficient in foreign exchange would be to make use of local materials and labor to the maximum extent possible in sanitary engineering projects and to minimize the use of materials which must be imported. Since the engineering fee is paid for as a part of payment for machinery and equipment under the old practice, there is little incentive to minimize these items. The advantage of divorcing the purchasing of engineering from the purchasing of equipment and machinery is good practice in America, and it is infinitely more advantageous in countries such as Pakistan.

The following are examples of how imported equipment and materials can be loaded in a design in place of local materials and labor: The use of pipe lateral underdrains in filters in place of false bottom or precast concrete construction, the use of air wash in conjunction with water wash in place of water backwashing alone, the use of mechanical mixing in place of baffled mixing chambers, the use of mechanical clarifier basins in place of manually cleaned sedimentation basins. What may be the latest and most economical design in a highly developed country, may not necessarily be sound engineering in a country where economic conditions are entirely different.

In sewage treatment design, the same reasoning can be applied to the choice of type of treatment. The trickling filter type of plant should have priority over the activated sludge type. In the trickling filter type, power requirements are small; the trickling filter except for the rotary mechanisms can be made entirely of local materials in most countries where masonry and concrete construction are common; operation of the plant is simple and the plant is easy to control. In the case of the activated sludge type, power requirements are high; air compressors, air piping and diffusers are needed, and since the plant is tempermental, it requires higher skill for operation.

Water Problems of Karachi

The water problems of Karachi can be summed up in the terms "too little and "too late."



LEGEND
MAIN ROADS
RAILROADS
RESIDENTIAL AREAS
CENTRAL COMMERC
LOCAL COMMERCI
INDUSTRIAL & PORT
MILITARY AREAS
PUBLIC INSTITUTION
CIVIL AIRPORT
280 FIGURES INDICATE POPULATION IN TH
SPORTS FIELD
Pop 5000
GRAMMAR & TECH SCHOOL
PARK
Pop 3500
PRIMARY SCHOOL
MOSQUE
Pop 3500
MODERN SCHOOL
SPORTS FIELD
INDUSTRY
LEGEND
RESIDENTIAL AREA
INDUSTRIAL AREA (200 ACRES)
COMMERCIAL AREA
MOSQUE
PUBLIC BUILDING AREA
OPEN SPACES
GRAPHIC SCALE IN MILES
A NEIGHBORHOOD UNIT
GOVERNMENT OF PAKISTAN
THE GREATER KARACHI PLAN
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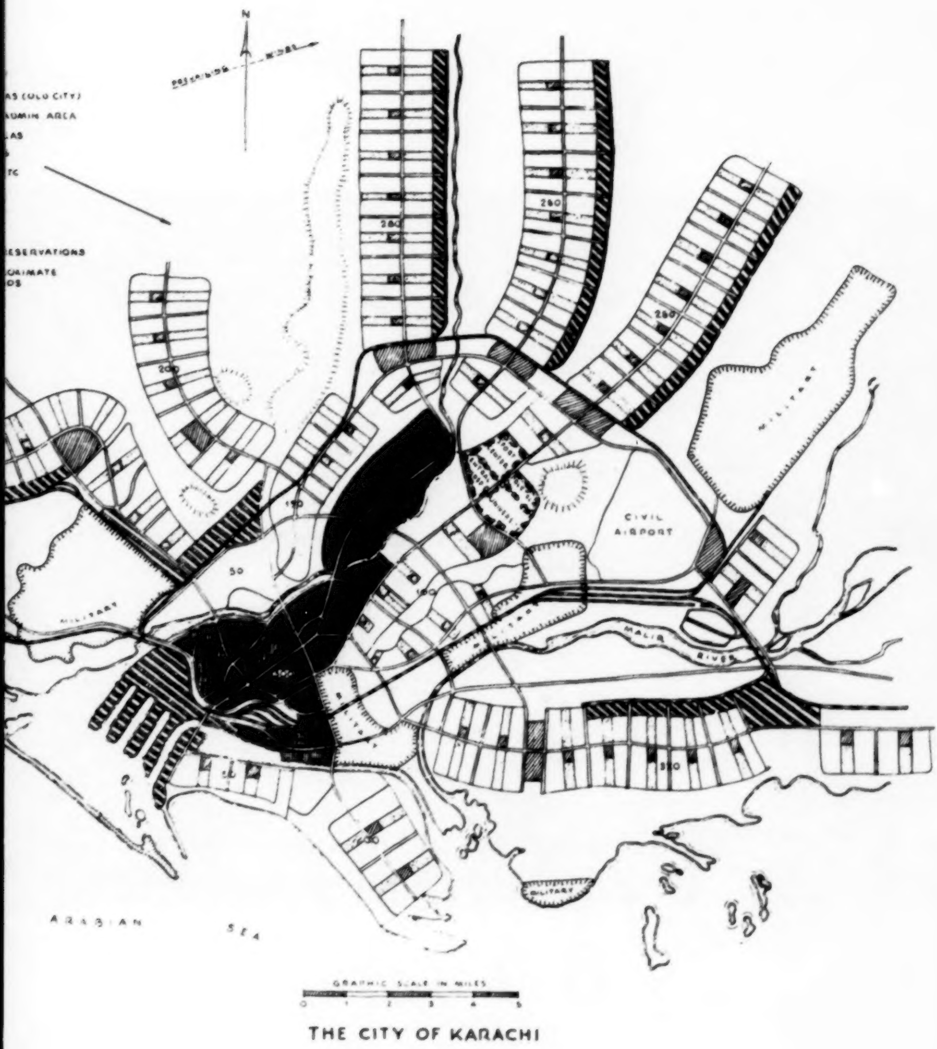
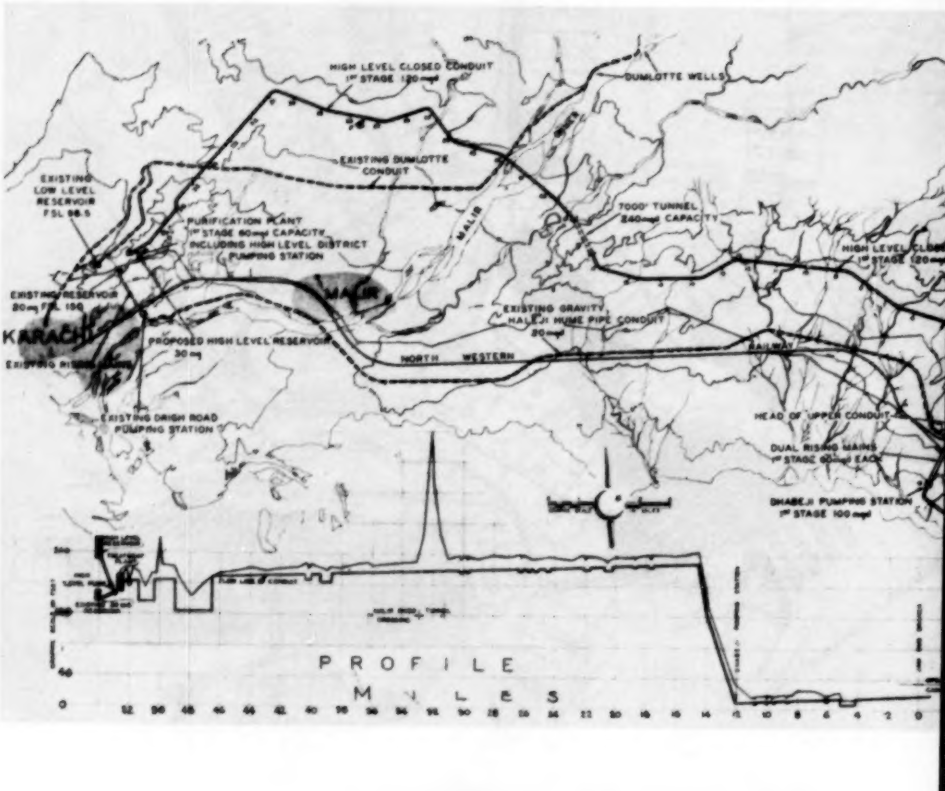
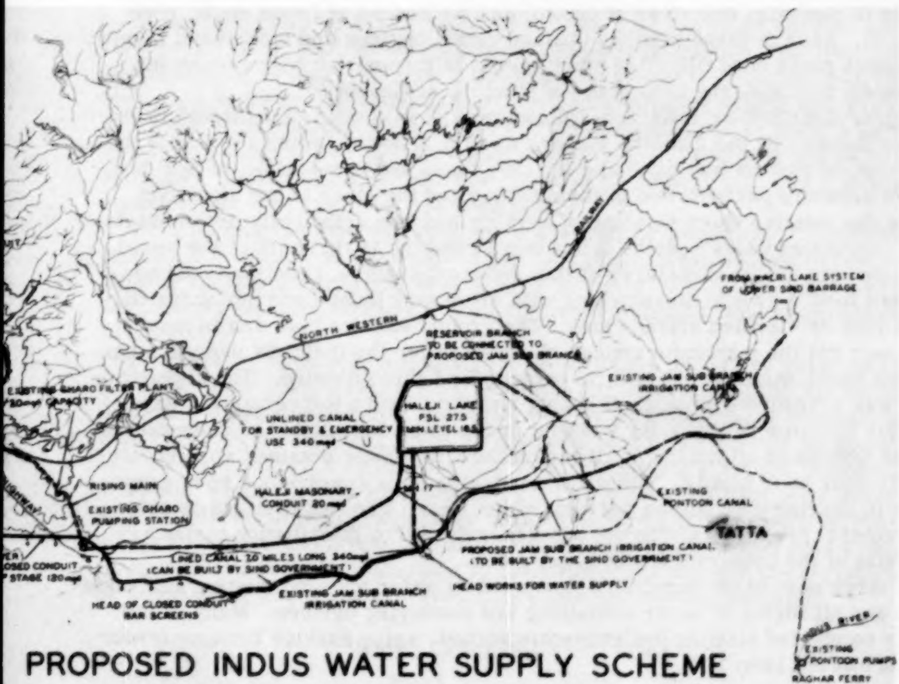
MERZ RENDEL VATTEN · PAKISTAN
CONSULTING & DESIGNING ENGINEERS



THE CITY OF KARACHI

PLATE 1


HIGH LEVEL CLOSED CONDUIT
1ST STAGE 120 mgd
DUMLOTTE WELLS
EXISTING DUMLOTTE CONDUIT
EXISTING LOW LEVEL RESERVOIR
PURIFICATION PLANT 1ST STAGE 60 mgd CAPACITY INCLUDING HIGH LEVEL DISTRICT PUMPING STATION
MALIR
7000' TUNNEL 240 mgd CAPACITY
EXISTING RESERVOIR 20 mg FSL 150
KARACHI
EXISTING GRAVITY HALEJI HUME PIPE CONDUIT 20 mgd
PROPOSED HIGH LEVEL RESERVOIR 30 mg
NORTH WESTERN
RAILWAY
EXISTING DRIGH ROAD PUMPING STATION
HEAD OF UPPER CONDUIT
DUAL RISING MAINS 1ST STAGE 60 mgd EACH
DHABEJI PUMPING STATION 1ST STAGE 100 mgd
PROFILE
MILES



PROPOSED INDUS WATER SUPPLY SCHEME
AND EXISTING SYSTEMS

PLATE 2

The old town, having a relatively small population and with the Dumlotte wells supplying some ten million gallons per day (MGD) by gravity, had an ideal water supply. (See Plate 2). The development of important war bases there during World War II created a need for additional supply which came in 1943 with the development of ten MGD in the new Haleji supply from the Indus. An additional ten MGD has been made available from this supply by installations made in 1952 and 53. However, with all of this supply, the population of some 1,200,000 has only 25 gallons per day per capita (gpdpc).

The Haleji supply has many unique features. In its inception, it was planned to utilize the flood height of the Indus to replenish seasonally the storage in Haleji Lake through "inundation" canals, "inundation" being the term used to describe canals which flow only during the flood season. The losses in the impoundment, however, were too great, being eight feet annually or equivalent to 35 MGD. Therefore, pontoon pumps (pumps on barges) were employed to replenish storage during low water periods. The supply had two stages of pumping, one stage at Gharo, and the second at Drigh road. (See Plate 2). Each of these stations utilized diesel engines and centrifugal pumps. A modern rapid sand filtration plant serves this supply on high ground immediately following the first stage of pumping at Gharo.

Water distribution in Karachi follows practices without counterpart in the United States. At the time the authors were in Karachi, water service in the distribution system was available for only three and one-half hours per day in two separate periods, one in the morning and the other in the afternoon. While the relative short duration of service was due principally to the shortage, continuous water service is not usual practice in that part of the world. To cope with the disadvantages of this deficient service, practically all consumers have a ground storage tank with necessary pumps and piping for filling a roof or elevated storage tank. The ground storage tank was to insure that each got the maximum amount of water under the deficient pressure conditions which would be the natural outgrowth of this situation. The elevated tank was to insure continuity of supply under pressure throughout the day.

This practice is obviously wasteful and is most inequitable to consumers. Those who could afford the facilities on their premises obtained an adequate twenty-four hour supply. The mains supplying their twenty-four hour usage were in service only fifteen per cent of the time. The installations on the consumers' premises and in the unnecessarily large distribution mains are wasteful of the country's limited resources.

A large part of the population is served by water purveyors using goat-skin bags and all forms of water containing and conveying devices. Many of the newly completed housing projects were without water service because feeder mains had not been laid.

Proposed New Water Supply

The obvious answer to an adequate water supply for Karachi lies in the utilization of the Indus as the source of supply. No other suitable supply is available. The decision to develop this source in large amounts had been made several years before the authors arrived in Pakistan. An amount of water equal to 243 MGD had been allotted to the Karachi Joint Water Board as a part of the development of the plans for the Lower Sind Barrage (Dam) on the Indus at Hyderabad about 120 miles from Karachi. This dam also provides water for a large irrigation project. The construction work on the project was well under way in 1951 and was expected to be completed by 1955.

The water allotted will be made available at Gujo at the lower end of the irrigation canals about 65 miles from Karachi.

The proposed Indus Water Supply Scheme is shown on Plate 2. The system consists of a first section of seven miles of open lined canal, followed by twelve miles of closed conduit which terminates at the proposed Dhabeji pumping station. At this point the water is to be pumped through force mains to the head of the gravity conduit about two miles away. The gravity conduit continues for 38 miles to the head of distribution where a treatment plant and high level pumping station will be located. All of the old city and a large part of the new developments can be served by gravity from this point utilizing the existing 20 million gallon (MG) reservoir. Other higher areas would be served from the high level system utilizing a proposed new 30 MG reservoir at a 70 foot higher level.

Most portions of the supply system would be built in stages to conserve initial capital investments. An initial development of purification facilities in the amount of 60 MGD was suggested. This would provide Karachi with a total supply of 90 MGD or 60 gpdpc for 1,500,000 population. By 1960 when the population is expected to be 2,000,000, the second stage of 60 MGD of treatment and pumping would be added to make the total supply 150 MGD or 75 gpdpc. The ultimate development for 3,000,000 population when a second 120 MGD conduit would be built would provide a total supply of 270 MGD or 90 gpdpc. These values all represent maximum supply rates and it would be expected that average rates would be less.

Preliminary estimates of cost and a schedule of construction were determined. The estimated total cost of the first stage of the project providing 120 MGD of conduit capacity, 60 MGD of firm pumping capacity and 60 MGD of purification capacity, exclusive of distribution facilities, was approximately $24,000,000.

It was only possible to speculate on the probable pattern of water use daily and seasonally since no data were available for determining the variations in demand. A recommendation was made that an ultimate goal of continuous water service be achieved. With an adequate supply, this would be possible and the wasteful practice of providing dual storage and pumping on consumer premises would no longer be necessary. The practice of part time water service and the uncontrolled customer rehandling of water negate the effect of modern methods and treatment in providing a bacteriologically safe supply. Recontamination in the mains due to back siphonage and due to carelessness on consumers' premises are inevitable under the current practice.

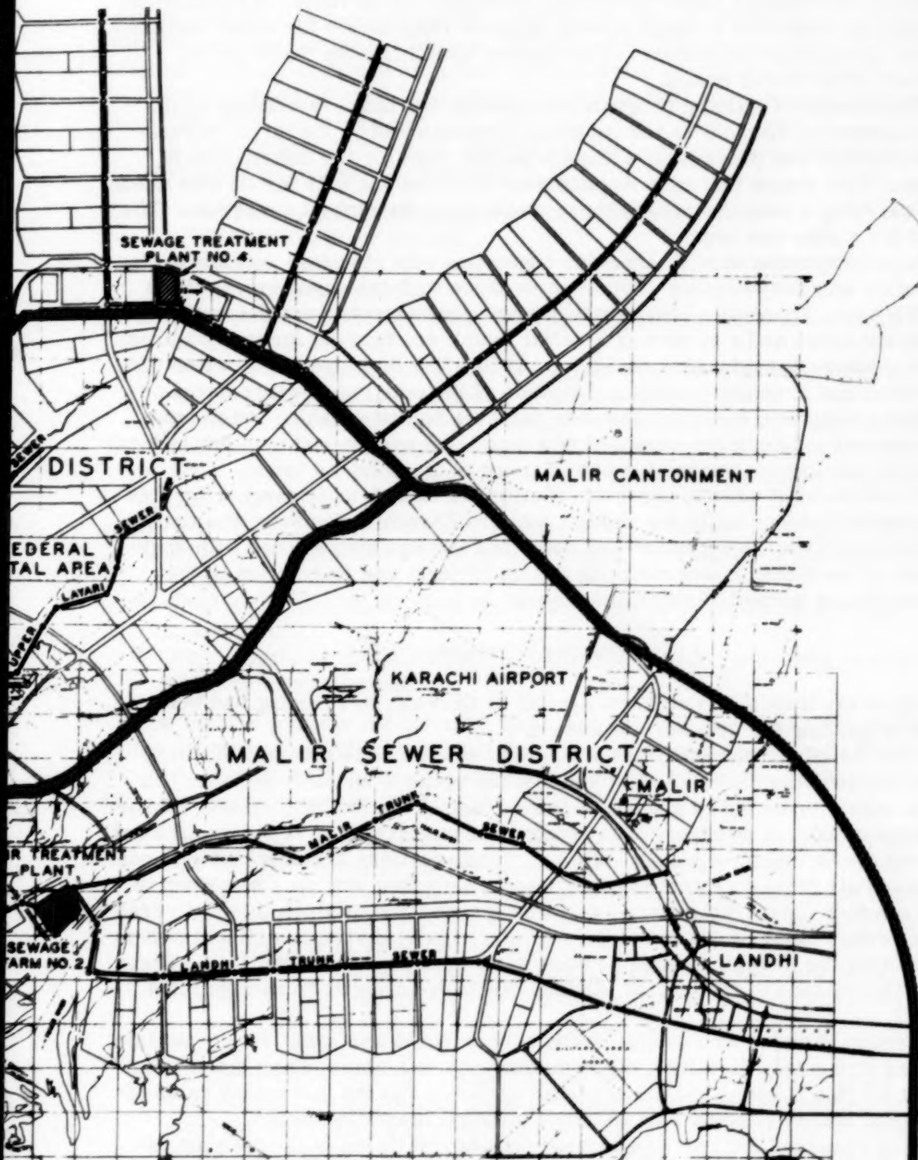
Water Distribution Problems

While much work had been done in preparing a plan for the water supply, no plan of distribution has been developed prior to the authors' visit.

The Karachi Joint Water Board is a purveyor of bulk water made available at the site of certain reservoirs. There were four reservoirs in 1951. Distribution agencies which had separate transmission mains to these reservoirs, included the following:

Municipal Corporation
Improvement Trust
Pakistan Public Works Department
Port Trust
Sind Industrial Trading Estates
Northwestern Railway.


GREATER KARACHI
PAKISTAN
TO SEWAGE FARM OR TREATMENT PLANT
ORANGI TRUNK SEWER
LAYARI
SEWER
SEWAGE TREATMENT PLANT NO. 3.
RISING MAIN
PUMPING STATION
NAZIMABAD
GUJRO
LAYARI TREATMENT PLANT
MAURIPUR CANTONMENT
SEWAGE FARM NO. 1.
LOWER LAYARI SEWER
RISING MAIN
EXISTING PUMPING STATION
RISING MAIN
PROPOSED PUMPING STATION
KIAMARI
CLIFTON
TRUNK SEWER
ARABIAN SEA
MANORA
LEGEND
SEWER DISTRICT BOUNDARY
PROPOSED TRUNK SEWER
FUTURE TRUNK SEWER
PROPOSED SEWAGE TREATMENT PLANT
FUTURE SEWAGE TREATMENT PLANT
PROPOSED PUMPING STATION
FUTURE PUMPING STATION
EXISTING SEWAGE EJECTOR STATION



MASTER PLAN FOR
GREATER KARACHI SEWERAGE SYSTEM
PLATE 3

The wastefulness of running parallel lines to these reservoirs by the many agencies distributing water to ultimate consumers is obvious. A recommendation was made that a single agency be made responsible for water distribution to the ultimate consumer. This agency most logically would be the Karachi Joint Water Board.

The extensive building program for housing and industry created by the development of Karachi as the capital of Pakistan and by the large increase in population was proceeding without a master plan for the distribution of water. This meant that each development was planning only for its own needs and carrying a supply main for these needs from the closest reservoir. The need for a plan was urgent.

In collaboration with all agencies concerned with planning, population distribution was projected for 1960 in accordance with the development of the MRVP plan. Using this basic study, water requirements were determined for separate areas and a system of arterial mains was laid out for the two pressure systems considered necessary by 1960. The development of water distribution and pressure facilities for some of the outlying satellite towns on higher ground was to utilize separate pumping facilities taking water from the nearest mains in the proposed new high level system and pumping to local gravity storage reservoirs for one or more of the satellite towns.

There was not time to carry the studies far enough to determine the size of arterial feeders while the authors were in Karachi. However, the routing of the mains was developed by the time they left and they worked with engineers of the Water Board outlining design criteria and instructing in the Hardy Cross method of network analysis.

Sewerage Problems

Up to the time of the author's arrival in Karachi, no planning had been done regarding the sewerage problems.

The old city of Karachi had an excellent sewage collection and disposal system since the old city is flat and low and because an early decision had been wisely made not to discharge raw sewage to the sea, the system entailed a large amount of pumping. The sewage is concentrated in separate areas at twenty Shone ejector pumping stations. These stations are supplied with compressed air from a central steam driven compressor station. Seventeen of the ejectors discharge sewage into force mains through which it is delivered to a sewage pumping station employing electrically driven centrifugal pumps to deliver the sewage through a rising main to sewage farm No. 1 (see Plate 3). The balance of the ejector stations discharge directly to sewage farm No. 2.

Sewage farming as a means of ultimate disposal was excellent at the time it was conceived. However, the expanding city was approaching the areas used for this purpose and the attendant nuisance and the increasing value of the land necessitated that an alternate disposal means be sought.

The impact of the lack of adequate disposal facilities in the outlying expanding areas was obvious. Collection systems and disposal means were urgently needed to keep pace with the housing developments. These developments almost without exception included adequate laterals and subtrunk mains. The fact that adequate water supply was not available in these areas had altered the nature of the problem, at least temporarily. Night soil collection and disposal at the sewage farm had to be resorted to until the water borne facilities could be put into complete use.

The problem in the old city was equally perplexing. The overcrowding and the expansion within the city had overloaded the old sewage system and during peak flow hours sewage was discharging out of manholes into the city streets and into the water courses. Some of the difficulties were due to the poor state of maintenance of the old sewers which resulted from the fact that the inexperienced Moslem operators had to take over the sewage system when the Hindu administrators left.

The various problems which existed and the questions which must be answered could be outlined as follows:

1. What means of ultimate disposal should be provided—
   a. Outfall sewer to the sea
   b. Sewage farming
   c. Sewage treatment.
2. If treatment is decided upon, what type and degree of treatment should be used.
3. How should drainage districts and areas be divided to determine the number of points of concentration for ultimate disposal.
4. What system of trunk sewers should be installed to keep pace with development and to conduct sewage to the points of ultimate disposal.
5. What means of relief should be adopted for the overloaded sewage system of the old city.
6. What changes in sewer design criteria and practice would be beneficial.
7. What policy should be adopted with regard to disposal of industrial wastes.
8. What reuse can be made of the effluent and by-products of sewage treatment.
9. What should be the administrative organization for providing sewage collection and disposal.

The master plan for the Greater Karachi sewerage system as developed by the authors in collaboration with Pakistani engineers is shown in Plate 3.

With regard to the questions and problems outlined above, the following decisions were made for the reasons given:

1. The disposal of untreated or partially treated sewage directly to the sea was not recommended because:
   a. The sea port and ocean recreational beach areas were important to Karachi with its limited recreation opportunities and contamination of these areas should be avoided.
   b. The desert character of the surrounding country and shortness of water supply indicated an advantage in the reuse of sewage treatment plant effluent for industry and for the irrigation of public parks or other areas.
2. Complete treatment was recommended for ultimate adoption in the watersheds flowing toward the sea. This would involve complete treatment for the Layari plant and the early adoption of complete treatment at the Malir plant located at the site of sewage farm No. 2 because of the high ground water there and the unfavorable sewage farming conditions.
3. The trickling filter type of plant was recommended because of reasons discussed herein relating to the adaptation of engineering practice to the local situation of low labor cost and limited foreign credit. Its simplicity of operation was another reason.

4. The development of two major sewerage systems in the Malir and Layari river watersheds was recommended with separate systems proposed for some of the outlying satellite towns when they would develop. One of these towns would lie in the Hab river watershed where gravity flow to a remote sewage farm would be possible. Several satellite towns to the east lie in areas directly tributary to the sea where a separate sewage treatment plant coult be justified. Several outlying satellite towns in the Layari watershed could be served by a separate plant whose effluent could flow to downstream areas by gravity where it could be used for irrigation. This would be less expensive than initially enlarging the trunk sewers in the lower watershed which must be built for earlier developments. An option could be exercised later to run a separate trunk sewer to the Layari treatment plant where this treatment plant would have to be enlarged.
5. The routing of trunk sewers in the Malir and Layari systems was recommended, and design tables indicating tentative sizes and slopes were submitted.
6. Recognizing that the development of a program for the relief of the sewers of the old city was a project of field investigation (no useful drawings existed of the old system) which would entail six months to a year of staff work, the authors outlined in detail the steps and procedures to be taken in making these studies. A decision was made that the method of improvement and relief adopted would not change the existing points of disposal of sewage, i.e., to sewage farms No. 1 and No. 2 where treatment facilities were to be installed as part of the master plan.
7. Sewer design and construction standards adopted by State Boards of Health in the United States were left with those in charge of sewer design for consideration in the changing of local practice where design problems are known to exist. Reference has already been made to the problems of velocity, slope criteria, and connection practices.
8. Recommendations were made that sewage treatment plant effluents be utilized to maximum extent possible for industrial operations and for the irrigation of public areas. Following the practice which is prevalent in that part of the world, sewage solids after digestion would be used for fertilizer. Gas engines for the recovery of power were recommended if funds were available.
9. It seemed that a policy of treatment of industrial wastes along with the other sewage would be the only satisfactory recommendation in view of the need for stimulating industrial development. Some exception to this might be necessary in special cases.
10. It was recommended that a sewerage board representing all affected agencies be set up for administering the sewerage facilities. In view of the close relationship of the functions of water supply and sewerage collection and disposal, it was suggested that the scope of the Karachi Joint Water Board be enlarged to include the sewerage problems also.

An estimate of cost and a construction schedule and budget were submitted. The schedule was carried through 1960 and entailed expenditures amounting to approximately $15,000,000.

Present Status of Projects

Recent communications from Pakistan indicate that the recommended plans for both the sewerage and water projects have been officially adopted. Due to the financial and policital problems in that troubled section of the world, the work is not going forward according to schedule. At present, work is under way on the construction of the conduits for the water supply. A German firm has been awarded the contract for the water filtration plant. The Layari sewage treatment plant is in the process of design, and it is understood that biofiltration has been the type of treatment adopted.